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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE INFORMATION REPORT

SAE J1436 | REV. JUL95

Issued 1983-09
Revised 1995-07

Superseding J1436 JUN89

Submitted for recognition as an American National Standard

(R) REQUIREMENTS FOR ENGINE COOLING SYSTEM FILLING, DEAERATION, AND DRAWDOWN TESTS

Foreword—This Document has also changed to comply with the new SAE Technical Standards Board format.

1. ***Scope***—This SAE Information Report is applicable to all engine cooling systems used in heavy-duty vehicles and industrial applications.

1.1 **Purpose**—The purpose of this document is to list the requirements which are in general use for filling, deaeration, and drawdown of engine cooling systems for heavy-duty and industrial applications. The material presented in this document is for information purposes only, and does not constitute a SAE Standard.

2. ***References***—There are no referenced publications specified herein.

3. ***Leveling***—Before starting any test, the vehicle or the industrial equipment must be level.

4. ***Filling***—With the engine off, thermostats closed, a completely drained system (including heater, other accessories, and their lines) must fill with cold water at 19 L/min ± 2 L/min (5 gpm ± 0.5 gpm) with hose until the filler neck overflows. Engine manufacturer's instructions on venting the engine and accessories must be followed to achieve the 19 L/min (5 gpm) fill rate.

Close shutters or block the airflow to the radiator with cardboard segments and run the engine at approximately rated speed without radiator cap until the thermostats open. The opening of the thermostats may be detected by observing the flow in the radiator inlet line sight glass, by noting a sudden rise in inlet line or top-tank temperature, or by noting when the coolant temperature exceeds the thermostat rating by 3 °C (5 °F). Continue running the engine for 5 min, and then stop the engine and measure the amount of water required to refill the system to the 100% full point, which is defined to be at the bottom of the filler-neck extension (cold-fill level) or to the recommended cold-fill "Full" mark if there is no filler neck extension.

The quantity of water added shall not exceed 10% of the total system capacity, defined in this document. An engine manufacturer may grant permission in a specific case to exceed 10% of total system capacity, but in no case shall the quantity of water added exceed the system drawdown rating, defined in this document.

The test applies in general to systems of up to 95 L (100 qt) capacity. However, lower fill rates [for example, 11 L/min (3 gpm)] may be required in special instances and will be specified by the engine manufacturer. For systems over 95 L (100 qt) capacity, the engine manufacturer may call for a higher fill rate in order to keep the total fill time to a reasonable period.

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In addition, in certain instances where air entrapment in the fill line (shunt line) may be suspected, the engine manufacturer may call for a bucket fill test. In larger systems, particularly those with remotely mounted heaters, manual air-bleed vent valves may be required.

5. ***Expansion Volume—***The radiator must provide an expansion volume equal to a minimum of 6% of the total-system capacity. This expansion volume will remain empty during a cold-fast fill, but provision shall be made to vent the air from this space to the filler-neck during normal gradual engine warm up. The amount of water required to slow fill the radiator from the bottom of the filler-neck extension to the breather hole [usually 3.2 mm (0.12 in) diameter] in the filler-neck extension, expressed as a percent of the total-system capacity, is the percent expansion volume.

Provision for a filler-neck extension tube is the preferred construction for radiators for heavy-duty and industrial applications. However, if a filler-neck extension is not provided, the amount of water required to fill the radiator from the recommended "Full" mark to the bottom of the filler neck, expressed as a percent of the total-system capacity, is the percent expansion volume. Total-system capacity is defined following the requirements for drawdown testing.

6. ***Deaeration Tests—***Engine manufacturers require tests of the cooling system deaeration capability to remove gases from the coolant during operation. These gases may originate from air entrainment during filling, from vortexing at the fill line (shunt line) connection when a vehicle is not operating on a level surface or due to centrifugal forces in a prolonged turn, or from combustion gases leaking across cylinder-head seals.

Because of the differences in the approach and the test methods of the various engine manufacturers, it is important that these tests be performed strictly in accordance with the engine manufacturer's requirements.

A brief description of some of the deaeration tests required by various manufacturers is given in the document for general information only. Refer to the engine manufacturer's requirements for details.

Deaeration tests are to be performed after determination of the expansion volume.

After determination of the expansion volume, replace the operating thermostat(s) with blocked-open thermostat(s) and refill the system with a hose until the filler-neck overflows. Run the engine at approximately rated speed for 5 min and refill the system to the bottom of the filler-neck extension or other "Full" mark. One or more of the following deaeration tests may then be required:

6.1 **Test 1 (Deaeration of Fill-Entrained Air)—**Run the engine at an approximately rated speed with blocked open thermostat(s), without a radiator cap, and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top-tank temperature of 65 °C ± 6 °C (150 °F ± 10 °F). Run until a sight glass in the engine outlet (radiator inlet) runs clear of air bubbles. The time from refilling to the bottom of the filler-neck extension until the sight glass runs clear of bubbles shall not exceed 25 min.

6.2 **Test 2 (Continuous Deaeration)—**Using a special vented radiator cap with the vent hose led to an inverted water-filled bottle set in a bucket of water for purposes of measuring the volume of vented air, run the engine at approximately rated speed with blocked-open thermostats and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top-tank temperature of 65 °C ± 6 °C (150 °F ± 10 °F).

Inject air into the system and measure the volume of air vented by the deaeration system while monitoring the pump-pressure rise. The rate of air venting when a 35% loss in pump-pressure rise occurs must equal or exceed an amount specified for each engine model.

6.3 **Test 3 (Continuous Deaeration)—**With the radiator cap on, run the engine at an approximately rated speed with blocked open thermostats and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top-tank temperature of 65 °C ± 6 °C (150 °F ± 10 °F).

Inject air at a rate specified for each engine model [approximately 2.8 L/min (0.1 cfm) per cylinder] and monitor the water pump flow. At the specified air-injection rate, the water pump flow must not fall below 50% of the original value, and the coolant loss through the overflow line must not be more than the drawdown rating (determined in Section 7).

7. ***Drawdown—***Test determines the reserve quantity of the cooling system and the correct position of the low mark in the radiator top tank or expansion tank.

7.1 **Test 1—**Run engine at rated engine speed with blocked open thermostats, without a radiator cap and with shutters closed or the radiator blocked with cardboard to maintain a top tank temperature of approximately 82 °C (180 °F). Start with the radiator brim full and record the water pump pressure rise to establish a reference pump rise, then drain off water in increments of 1 L (1 qt) at a point of positive pressure and record pump pressure rise after each unit of water is removed. Remove water slowly until there has been a 15% loss in pump pressure rise from the reference pump rise. The water pump rise loss at the low coolant level mark must not be more than 10% from the reference pump pressure rise. The volume of water drawn from the system, expressed as a percent of the total system volume, is the drawdown volume. This volume must be equal or greater than 12% of the total system volume and is expected to include the expansion volume as described in Section 5 plus another 6% of more of the system volume between the full mark and low mark.

7.2 **Test 2—**After the deaeration tests, run the engine at governed no-load speed, with blocked-open thermostat(s), without a radiator cap, and with the shutters closed or the radiator blocked with cardboard segments to maintain top-tank temperature at 65 °C ± 6 °C (150 °F ± 10 °F). When the temperature is reached, add or draw off water until the system is filled to the bottom of the filler-neck extension or the other "Full" mark. Then draw off water slowly in 1 L (1 qt) increments from system at a point of positive pressure and measure until air is seen in engine-outlet sight glass. The amount of water drawn off, expressed as a percent of total-system capacity, is the drawdown rating. This must be equal to or greater than 11% of the total-system capacity, but not less than a specified minimum, for systems up to 95 L (100 qt) capacity. For most manufacturers, this specified minimum drawdown rating is 3 L (3 qt). However, some engine manufacturers require higher minimums. For cooling systems with capacity above 95 L (100 qt), the required drawdown rating shall be 10.5 L (11 qt) plus 4% of the system capacity in excess of 95 L (100 qt). If a remote surge tank is used and it is not located above or higher than all other system components, there may be additional drawdown test requirements. Review the design with the engine manufacturer.

8. ***Total System Capacity—***Following the drawdown test, drain and measure the water from the entire system, being careful that no fluid is trapped in the system. This volume of fluid drained, added to the amount drawn off during the drawdown test, is the total-system capacity.

9. ***Other Requirements—***Individual engine manufacturers may have additional cooling system tests or system parameters that they require. Refer to the engine manufacturer's requirements. A sampling of some of these requirements follows:

9.1 Pump Cavitation—Prior to the start of testing, be sure a blocked open thermostat is installed and the system is completely filled with water. In addition, some means will be needed to warm up the coolant such as disconnecting the fan belts, blocking fan airflow, etc. The pressure cap should be removed through the test. Starting with water pump inlet temperature below 49 °C (120 °F), record water pump inlet temperature and pump pressure rise as the water temperature rises while the engine speed is held constant at the rated speed. Record the pump rise at 49 °C (120 °C) as a reference pump rise. Control the coolant warm-up rate to approximately 2 °C (5 °F) rise every 2 min to assure accurate data, and record the pump inlet temperature and pump pressure rise at least every 5 °C (10 °F) below 85 °C (185 °F) and every 2 °C (5 °F) above 85 °C (185 °F) water pump inlet temperature. Adjust the pump pressure rise to the density of the water at 49 °C (120 °F), and observe the pump rise loss at each point. Continue running until either the system has exceeded the pump rise loss limit set by the manufacturer (usually either 10% or 20% rise loss) or has exceeded the minimum required cavitation temperature as specified by the manufacturer. Since altitude can have an effect on the boiling point of water, the final cavitation temperature should be adjusted to 100 kPa (29.6 in Hg) barometer pressure by adjusting the observed cavitation temperature by 0.33 °C for each kPa (1 °F for each 0.5 in Hg) the test site barometric pressure differs from 100 kPa (29.6 in Hg).

9.2 Water Pump Inlet Pressure Conditions—It is desirable that the water pump inlet pressure does not fall below atmospheric pressure. One of the following alternatives will probably be specified by the engine manufacturer:

9.2.1 WATER PUMP SUCTION—Suction at the inlet to the water pump shall not exceed 10.2 kPa (3 in Hg) at engine high idle, without a radiator cap, and with the thermostats open.

9.2.2 WATER PUMP INLET PRESSURE—There shall be a positive pressure above atmosphere at the inlet to the water pump at all times.

10. Special Considerations for Systems with Surge Tanks or Coolant Recovery Systems—An engine cooling system which has a surge tank can be considered to have a remote-mounted radiator top tank. For purposes of these tests, the surge tank shall be considered to be the radiator top tank. Filling should be accomplished through the filler neck on the surge tank. The surge tank will be provided with a filler-neck extension or the other cold-fill "Full" mark. The expansion volume for the system is provided in the surge tank in the same manner as in the usual radiator top tank. The total-system capacity includes the volume of the surge tank to the bottom of the filler-neck extension or the other cold-fill "Full" mark.

An engine cooling system which has a coolant recovery system can be considered to have a remote-mounted expansion volume only. For purposes of this test, filling should be accomplished through the radiator filler neck, filling to the bottom of the filler neck, and through the coolant recovery system tank inlet, filling to the recommended cold-fill level. The expansion volume for the system is provided in the coolant recovery system tank, and is equal to the volume from the recommended cold-fill level to the top of the tank.

11. Notes

11.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.